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THE

PSYCHOLOGICAL BULLETIN

GENERAL REVIEWS AND SUMMARIES

TROPISMS AND INSTINCTIVE ACTIVITIES

BY HARRY BEAL TORREY

Reed College

Allen (1) finds that *Planaria dorotocephala* is both positively and negatively rheotropic, the former in the stronger, the latter in the weaker current. The reaction can often be reversed by changing the velocity of the current, the composition of the water, and the temperature.

Arey (2) concludes "that while *Amphioxus* can swim backwards for short distances, its normal orientation in continued swimming is with the anterior end in advance." "It burrows in the sand tail first."

The experiments of Bittner, Johnson and Torrey (3) lead the authors to conclude that while the earthworm (*Allolobophora* sp.) exhibits random movements, its "orientation to light is determined essentially by movements that are predictable as to direction and hence neither random movements nor 'trials.'"

According to Brun (4), who discusses the problem of orientation in general and among the ants in particular, the distance orientation of the latter is an unusually complicated psychophysical process, through which, according to the governing conditions and the organization of the species concerned, experiences of very different kinds are achieved, involving topochemical, topographic, visual and kinæsthetic impressions, often alone, frequently, however, in combination.

De Burlet (5) corroborates the results of De Kleijn and Socin (17) with anatomical evidences from serial sections of the head.

Du Porte (6) describes the death-feigning reactions in the clover weevil, *T. picirostris*, including methods of producing the feint, death-feigning attitudes, variability and duration of the response, the effect of repeated stimulation, mutilation, chloroform and ether. The death-feigning instinct often appears to be non-adaptive, if not positively injurious. The reaction is segmental and not controlled by the supra-oesophageal ganglion.

According to Essenberg (7) the water strider, *G. remiges*, is a voracious and indiscriminate feeder, preying on various insects including mosquitoes. It is positively phototactic, thigmotatic, and rheotactic, and negatively geotactic. Its sense of sight is keen; the senses of smell and hearing are much more feebly developed. Its death-feigning reaction is easily produced, much less readily after numerous stimulations.

Essenberg (8) contributes the following facts about the back-swimmers (*Notonecta*). They are very voracious. Protected by a thick layer of surrounding air they are little influenced by chemicals. They are strongly positive to light, the reaction increasing with light intensity and temperature. They fly toward bright sunlight. At zero centigrade they lose their air and become heavier than water. They are positively rheotactic. The young hatch within 20 days and resemble the adult in behavior and instincts.

Garrey and Moore (9) find that sensory stimulation acting on the earthworm tends to set up peristaltic movements, and suggest the possibility that all normal peristaltic movement may be the result of sensory stimuli, a view differing from the views of Friedländer and of Biedermann, who ascribe peristaltic waves to traction, especially to the stretching of the myodermal sheath. Stimulation of the nerve cord near the middle of the worm produces shortening of the anterior part and lengthening of the posterior part, indicating that the responses are determined not by the nature of the stimuli, but by the direction the impulses travel in the nerve cord. The relaxation of the longitudinal muscles accompanying contraction of the circular set, and vice versa, are striking examples of reciprocal innervation.

The investigation by Goebel (10) of the two orchid genera *Phalaenopsis* and *Taeniophyllum* leads him to conclude that the dorsiventrality of their aerial roots is not autonomous, but is determined by the effect of light. On the illuminated side anatomical differentiation is inhibited and the outer cells form thicker walls. The suspicion that this form of the aerial roots might be evidence

for the inheritance of an "acquired character" is not supported by the facts.

Hargitt (11) corroborates Parker's observations on the Phototropism of *Vanessa antiopa*, cites evidence tending to show that this butterfly has a sense of locality, and regards as unsatisfactory the view that color pattern and wing pose have any sex significance.

According to the experiments of Harvey (12) the salt water lum nous bacteria used were killed by too great dilution of sea water with fresh water, owing chiefly to lowered osmotic pressure of solution rather than to the absence of salt. Also some salt is necessary for the continued production of light. Acids and alkalis in very weak concentrations prevent light emission, acids being more effective than alkalis, and inorganic more effective than organic acids. It is interesting that the bacteria live and phosphoresce in a pure sodium chloride solution, though of the other constituents of sea water, calcium chloride and magnesium chloride are very toxic when alone. Various alcohols exert an inhibiting action that is reversible. Saponin has no effect on these bacteria although exerting great cytolytic power on other forms in small concentration.

From his experiments on *Paramecium cordetum*, Hutchinson (13) concludes that the heat resistance of this organism is augmented when the animals coming from an alkaline culture medium are exposed to very dilute solutions of sodium chloride, calcium chloride, sodium chloride *plus* calcium chloride, potassium nitrate, sodium carbonate, or to distilled water. Coming from an acid medium, *Paramecium* is less resistant in solutions of calcium chloride and sodium chloride, but more resistant in the controls. The author finds no evidence of specific action of the salts in his experiments.

The paper by Kanda (14) is a clear and interesting general discussion of the subject of geotropism in animals with a bibliography of some 50 titles.

According to Kanda (15), *Littorina littorea* is both negatively geotropic and negatively heliotropic. Negative geotropism in sea water varies with the angle of inclination to the horizontal of the surface on which the animals move. The number of individuals responding negatively is larger, however, in the air over a moist plate. Roughness of the substratum appears to diminish the negative response. On the dry substratum the snails exhibit a degree of positive geotropism. Negative heliotropism interferes with the negative response to gravity in the direction of the sunlight. The author views the statolith theory as an explanation of the geotropism of *Littorina*.

Kanda (16) finds that *Physa gyrina*, *Planorbis trivolvis*, *Limnaea stagnalis*, and *L. columella* are negatively geotropic when their lungs are empty and positively heliotropic when their lungs are full of air. He is inclined to believe that *Physa* is naturally positively geotropic and possesses statocysts with statoliths which may be the organs of geotropic orientation. *P. gyrina* is negatively heliotropic.

According to the experiments of De Kleijn and Socin (17) the post-ganglionic sympathetic fibers for the eye proceed from the circular cervical ganglion, along the internal carotid for a short distance, then enter the middle ear which they leave as an independent nerve, entering the cranium through the superior orbital fissure along side the Bidian nerve. (See De Burlet (5).)

Krecker (18) concludes that *Hexagenia variabilis* orients positively to a breeze owing to tension exerted on the muscles of attachment. Similarly the negative position assumed with reference to gravity is attributed to the insect's means of attachment. Positive toward 16 c.p. incandescent lights, the insects took up their positions radially about such a light on a horizontal surface, facing it. On a vertical surface, the individuals above the horizontal would face away from, those below the horizontal toward the light. This variation was also attributed to factors connected with maintaining a foothold.

Lashley (19) has investigated the problem of orientation in noddy and sooty terns, by studying their nesting activities. In their recognition of the nest, both visual stimuli and motor habits are factors. The birds show no evidence 1, of any special sense of locality such as a magnetic sense functional within short flights; 2, of ability to re-trace paths by memory of successive directions and distances when these have been experienced but once. The conclusions of the author regarding the recognition of the young by parent birds are less definite. Notes on the modifiability of instinctive activities and the integration of complex habits complete the paper.

Loeb and Wasteneys (20) find not only that polyps of the animal *Eudendrium* obey the Bunsen-Roscoe law of photochemical action that Blaauw has already found to apply to the heliotropic curvature of plants, but that the "relative efficiency of the different parts of the spectrum of a carbon arc light for the production of heliotropic curvatures in the animal *Eudendrium* and in the seedlings of the plant *Avena* is practically identical."

The essential results contributed by Loeb and Wasteneys (21)

are embodied in their later papers (**22, 23**). Loeb and Wasteneys (**22, 23**), show that while "there seem to exist two types of heliotropic substances (or elements), one with a maximum of sensitiveness in the yellow-green region, and the second with a maximum of sensitiveness in the blue," these types are distributed independently of the boundaries between animals and plants. *Eudendrium* in the larvae of *Arenicola* among animals, and *Avena*, among plants, are most sensitive to blue light, though not to the same spot of the blue, while *Daphnia* and the larvae of *Balanus* are most sensitive to the yellow-green or yellow part of the spectrum. Further, "of the two green flagellates *Euglena viridis*, and *Chlamydomonas pisiformis*, the former is most sensitive to blue, the latter to greenish-yellow." The authors think "it is quite possible, however, that plants are more generally sensitive to the blue rays of the spectrum, while among animals those may prevail who are more sensitive to yellowish-green or yellow."

Mast (**24**) proposes to abandon the term *tropism* on account of the variety of senses in which it has been used by various authors.

Mast (**25**) records some observations on the remarkable behavior of *Fundulus* in escaping from sand beach tide-pools whose outlets close with the falling of the tide. "As to the mechanics of the process," the author is "quite in the dark." He excludes vision, and light reflected from the water, as sufficient causes. The fish leave the water usually on the seaward side of the pools.

According to Mast (**26**), the eye-spots in *Gonium* consist of an opaque cup-shaped part and a hyaline lens-shaped part. Orientation in *Gonium* is direct, the colonies always turning in the right direction. The author holds that it is "dependent upon the time-rate of change of light energy on the photo-sensitive substance, probably the hyaline portion of the eye-spot, and not upon the absolute change or the continuous action of light."

McDermott (**27**) has observed that house flies have a strong positive reaction to air currents, between temperatures of 27° and 40° C.

From data obtained by measuring the reactions of the blowfly larva to light from opposed sources, Patten (**28**) concludes; "1. The graph expressing the values of the angular deflection of the blowfly larva from an original path of locomotion at right angles to the line connecting the sources of light, produced by a graded series of percentage differences of intensity between opposed lights cannot be regarded as conforming to the Weber-Fechner Curve. 2. Graphs

expressing the values of the angular deflections produced by a graded series of absolute intensities of opposed lights having their relative intensity maintained constant, may be regarded as in conformity with the Weber-Fechner expectation. 3. The fact that two sets of data derived from the same animals, by identical experimental procedure, yield opposite conclusions so far as the Weber-Fechner Law is concerned, indicates that the agreement with the law, when it does occur, is a purely fortuitous one, and that the reactions of the blowfly larva to opposed lights are controlled by other factors. 4. It is possible to demonstrate geometrically that a photoreceptive mechanism operating after the manner of bilaterally located sensitive surfaces inclined at an angle to each other and affecting the opposite sides of the musculature in proportion to the stimulus they receive, would determine *both* types of curves which have been plotted from experimental measurements of the photic reactions of the blowfly larva."

Polimanti (29) notes the rheotropism of the tadpoles of *Bufo* and *Rana*, and suggests the possible usefulness of the reaction as a means of obtaining food.

Porcelli-Titone (30) finds that several species of bacteria, when exposed to ultraviolet light, lose the power to reproduce before the power to move. This suggests a special action of a very delicate nature upon the protoplasm of the organisms, and a further possibility that germs thus treated might be of especial value for purposes of immunization.

Rabaud (31) finds that the emission of dark fluid from the mouths of grasshoppers when captured is a reflex process following the stimulation of various localized surfaces of the body. The fluid comes from the crop. The abundance of its flow is determined in a given individual by the region stimulated. It flows most abundantly after lateral stimulation of the thorax, much less abundantly after stimulation, by pressure, of an anterior tibia. Similarly, the jumping reflex is stimulated mainly by blows on the ventral face of the abdomen that awaken no response of the mouth parts.

Rau (32) records nineteen experiments devised to test the behavior of mud-dauber wasps whose nests had been tampered with. The results differed with the individuals observed. In most cases where nests or their contents were disturbed, the owners at once detected the facts. But they often committed grave blunders, sealing empty nests, failing to lay eggs in well stocked nests, etc.

Rau and Rau (33) give an account of the nest-building activities of three species of mud-dauber wasps, accompanied by photographs of the nests, of the parasites that infest the nests of the various insects that occupy abandoned nests, and of the contents of the nests. It appears that these three species of wasps, with exceedingly similar structure and habits, differ remarkably in survivability, the least abundant species in the locality concerned thriving, strangely enough, far better than the others. In many cases, normal instincts went awry, as indicated in the previous review (32).

Shannon (34) distinguishes between the devastating marches of army worms and Rocky Mountain locusts on the one hand and true migrations on the other. In the category of true migrants he places the monarch butterfly and the dragon fly which appear both in this country and in Europe to fly northward in Spring, and southward in Autumn along routes which parallel the courses of migratory birds. Facts indicate that *Vanessa cardui* and other butterflies are also to be classed as true migrants.

The observations of Shelford and Powers (35) on the resistance of salt water fishes to contamination and decomposition products and their reactions to various physical and chemical conditions lead to a very interesting discussion of their habits, especially the migration and feeding habits of several species. It appears that herrings react to temperature differences as small as .2° C. and to hydrogen sulphide when not more than 0.5 c.c. per liter is present. Their reactions to acidity and alkalinity are exceedingly delicate. "These fish are as sensitive to acidity as litmus paper." "In connection with the entrance of salmon into freshwater. . . . it is evident that the orientation is with reference to acidity and alkalinity rather than salinity." The extreme degree of these reactions removes "the difficulty in fishes determining the direction to large rivers from hundreds of miles out at sea or finding their way into any bay, harbor, or river, or other arm of the sea which their particular physiological condition at a given time demands. It is not necessary to appeal to 'instinct' to explain the return of certain salmon to certain rivers or the running of herrings in certain localities."

Sturtevant (36) concludes from his experiments on *Drosophila* that neither sex exercises any choice in the selection of a mate. Sight is not essential in sex recognition. The olfactory and tactile senses are probably both concerned. The function of the wings in courtship is the production of sexual excitement in the female.

Swindle (**37**) finds that various birds and reptiles exhibit certain instinctive movements in rhythmic series and that the accustomed rhythms are modifiable. For example a cockatoo that showed a marked tendency to move its head and feet in multiples of 3 showed, after being subjected to passive movements in groups of 5, a similar tendency to react in multiples of 5.

Thompson (**38**) reviews certain contributions to our knowledge of heliotropism, which are published in Loeb's "The Dynamics of Living Matter," and in the papers of Loeb and Wasteneys (**20, 21**) which have already been considered.

After indicating the places of the selection theory and physiological analysis in the development of a science of behavior, Torrey (**39**) considers the relation of the Bunsen-Roscoe law of photochemical action to the phototropism of organisms and cites certain results recently obtained that extend its applicability to the behavior of the fruit-fly *Drosophila*.

According to Townsend (**40**), the flies *Cuterebra* and *Dermatobia*, while possessing reproductive systems presumably on the same practicable order, differ in the methods by which they are able to parasitize their hosts. *Cuterebra* has large eyes and small antennae. The essential stimuli leading to oviposition are probably visual. The eggs are deposited in large numbers in the runways of the rabbits, rats and other small rodents it infests, the maggots emerging upon close contact upon the bodies of the latter. *Dermatobia* parasitizes the larger mammals, including man, none of which live in burrows. It appears to utilize certain blood-sucking *Diptera*, including mosquitoes and deer-flies, as carriers of its eggs, capturing the carrier and gluing the eggs to the underside of the body. The maggots emerge upon coming in contact with the body of the host.

Turner (**41**) gives an account of various activities of the ant-lion, including methods of constructing its pit, feeding reactions, locomotion, the emergence of the imago from the chrysalis and the death-feint. Food insects and arachnids are distinguished from non-living objects by the restlessness of their movements. There is no characteristic death-feigning posture. The author agrees with James that the death feint is simply terror paralysis. Its duration, however, appears to vary around several maximal values.

Turner (**42**) describes picturesquely the mating of *Lasius niger* observed one September afternoon. Neither negative geotropism nor positive phototropism accounts for the behavior of the swarms that leave their nests for the nuptial dance. Mating takes place

in the air, never on the ground or shrubs, where the females obtain no response from the males. A crowd of flying ants fifteen or twenty feet above the ground was composed exclusively of males with the exception of single virgin females which cork-screwed through it now and then, followed by a few males. The nuptial dance took place on a single summer day, ending at sun-down.

The female false spider *Eremobates formicaria* Koch observed by Turner (43) was nocturnal. It constructed a burrow in dry, compact soil every night, resting therein during the day. It was a voracious feeder on various insects, consuming the soft parts as well as the juices of its victims. It pounced upon, and fed upon, dead insects when they were moved. It learned to avoid hairy caterpillars. Several batches of eggs were laid, each batch in a different burrow whose mouth was closed.

Wager (44) concludes that in *Eranthus*, *Tropaeolum*, and *Geranium*, the blade of the leaf is not, but that the stem, especially the apical centimeter of it, is heliotropically sensitive; "that the perception of light is located, probably, mainly in the cortex, but that the transmission of the stimulus may be conducted both longitudinally and transversally through any of the parenchymatous cells of the stalk." Whether the direction of the light rays or the difference of intensity of illumination on the two sides is the controlling factor in producing the heliotropic curvature is not determined. That it cannot be the former merely is indicated by the difference of the behavior of the leaf stem in blue rays, to which they react strongly, and red rays, to which they react weakly if at all.

Watson (45) gives an account of the experiments of himself and Lashley which are reviewed below. He also refers to his studies on the spectral sensitivity of birds, in which he shows that the spectral range of the pigeon almost exactly coincides with that of man, a result that eliminates Duchatel's view that the homing birds uses the infra-luminous rays.

Although Watson and Lashley (46) reach no explanation of homing, their experiments appear to dispose of various current theories of homing based on vision, cutaneous sensibility, magnetic sensibility, and the functioning of the semicircular canals. After recording various facts about the homing of pigeons, frigate birds, and other—especially domestic—vertebrates, they give an account of the Tortugas noddy and sooty terns, their colonial life, migration, feeding and nesting activities, swimming and resting on the water, and retention of nesting habits. Previous experiments on homing

at Tortugas are recapitulated and the experimental work on homing in 1910 and 1913 described, including flights from Key West, New York, Mobile, Galveston and points *en route* to the latter place. The authors conclude "that where proper conditions are maintained the noddy and sooty can home from almost any distance up to at least, 1,000 miles. Furthermore, the territory over which they take their flight apparently may be barren of any visual objects to which they previously may have established habits." The paper closes with suggestions for further investigation along what appear to be promising lines.

Wells (**47**) finds that fresh water fishes react to single salts in solution, or to combinations of antagonistic salts, in a way that tends to bring them into a region of optimum stimulation. The phenomena of antagonism are thus indicated by the behavior as well as the resistance of organisms. The fishes are less sensitive to salts than to hydrogen and hydroxyl ions. Starvation and over-feeding and acclimatization modify their reactions. The relation of the migrations of anacdromous fishes to rhythmic changes in their metabolism is discussed.

Wells (**48**) recounts experiments showing the importance of alkalinity and acidity in the reactions of fishes. He also cites numerous previous investigations in support of the conclusion he draws from his own work that, contrary to the usual view, a small concentration of hydrogen ions is beneficial rather than deleterious to organisms, and that the toxicity of distilled water may be due in large part to its neutrality.

Wheeler (**49**) describes some of the habits of *M. sanguinea* and quotes an account of a nuptial flight involving thousands upon thousands of individuals. He finds that *Myrmica*, the most primitive of existing ants, founds its colonies in precisely the same manner as the most highly specialized species.

Yerkes (**50**) records the behavior of a monkey toward her stillborn offspring. During a period of four weeks, until the corpse was reduced, through handling, decomposition and licking, to what looked more like a bit of rat skin than the remains of a monkey, the mother watched over it so assiduously that it was impossible to take it from her except by force.

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SENSORY PHYSIOLOGY OF ANIMALS

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The direction of interest in the study of sensory physiology seems to have changed little during the past year. Studies of photic reactions still predominate, but a somewhat greater interest in the chemistry of light reception is manifest. A number of papers on the sensitivity of lower organisms to chemicals have appeared, but these seem, for the most part, to be preliminary studies without analysis of the receptors involved. The most thorough studies in their respective fields and the ones which should arouse the greatest interest are those of Buddenbrock (**6**) and Mast (**28**).

Sensory Reinforcement.—Cary (**8**) finds a reduced rate of metabolism (measured by the CO_2 produced) and of regeneration in the medusa, *Cassiopea*, after removal of the marginal sense organs. His experiments show that this is not merely the result of the diminished muscular activity following the removal of the organs. Horrax (**16**) sectioned the tracts of Flechsig and of Gowers in the dog and traced the degeneration of the cord and cerebellum. The ventral spino-cerebellar bundle was restricted to the cephalic half of the cerebellum; the dorsal to the caudal half of the vermis and the medial portions of the lateral hemispheres. No disturbances of behavior except those referable to the loss of muscle sense and tonus were found and almost complete recovery followed.

After treatment of a restricted area of the motor cortex with strychnine, Amantea (**1**) found, before the onset of diffuse excitability, a period during which clonus of the muscles supplied by the area could be excited only by stimulation of a restricted group of cutaneous receptors. When the area for extension of the toes, determined by faradization, is strychninized this reflex is elicitable only by stimulation of the dorsal surface of the same foot. Similarly, for contraction of the toes the plantar surface of the foot must be stimulated.

Tactile and Organic Receptors.—Barrows (**5**) describes the accurate orientation of the orb-weaving spider to localized vibrations of its web. Amputation of each pair of legs singly did not disturb the reaction. The behavior is described as a "positive vibrotaxis" (a reaction to unequal stimulation of symmetrical parts) but this is not borne out by the experiments. Krecker (**21**) notes the positions

assumed by ***Ephemeridæ*** with respect to the source of light and to gravity and the compromise in the reaction to these stimuli in combination. Crozier (**10**) and Sayle (**34**), give data on tactile excitability in connection with their general studies on cutaneous sensitivity reviewed below.

Sensitivity to Chemicals.—Crozier (**11**) denies Coghill's view that sensitivity to high concentrations of chemicals applied to moist peripheral surfaces is due to stimulation of tactile and pain receptors through the destruction of the germinative layers of the skin. Evidence is given to show that in the frog there is no correlation between the penetration of the skin by the chemical and the exciting effect of the solution. Cocainizing destroyed sensitivity to pinching but not to formic acid. The receptors for the common chemical sense are distinct from those for tactile stimulation. From experiments on *Ptychodera* the same author believes that this organism has generalized receptors open to stimulation by both chemical and mechanical means since these elements could not be isolated by fatigue (Crozier, **9**). In an extensive study (**10**) he finds sensitivity of Holothurians to light, contact, and chemicals but not to heat. A negative crawling reaction is given to light and a quick contraction of the tentacles and other organs to sudden shading. Avoiding reactions are given to acids, bases, salts, alkaloids, to maltose among carbohydrates, and to volatile oils. The chemical sensitivity resembles that of the earthworm. In a study of the pithed frog (**12**) Crozier finds antagonism in the exciting effects of the salts of sodium, calcium, and potassium.

Moore and Kellogg (**30**) describe the movements of the earthworm in a constant electric current.

Studies of the olfactory sense of insects have been extended by McIndoo (**29**) to fifty species of beetles, eleven of which were tested experimentally for the location of the olfactory organs. The experiments limit the olfactory function to the pores (organs of Hicks) on the elytra, wings, legs, and mouth-parts of the beetles.

Shelford and Powers (**35**) find that herring, in the gradient tank, show a sensitivity to 0.6 degrees C. (possibly to 0.2 degrees C.) and react negatively to an 0.045 per cent. solution of hydrogen sulfide. Acute sensitivity to the oxygen, salt, and acid content of the water appears in these and other marine fishes. The importance of such sensitivity in determining the migrations of fishes is emphasized. Seven species of fresh-water fish were tested by Wells (**38**) for sensitivity to dissolved chlorides, nitrates, sulphates, and combinations

of these. With antagonistic salts the fishes choose the optimum part of the gradient tank.

Howat (17) found that cutaneous sensitivity of the frog to chemicals is reduced by injections of nicotine. The duration of paralysis of the cutaneous receptors and the time required for recovery varies for different areas of the skin. Reflexes to deep-lying receptors are not affected by the drug. Sayle (34) reports experiments on the cutaneous sensitivity of the mud-puppy to tactile, chemical, thermal, and photic stimuli, to all of which the amphibian reacts with an intensity varying with the region stimulated. Excitability to acids is proportional to the degree of ionization. Animals fatigued by HCl showed reduced tactual excitability while sensitivity to other chemicals remained. If by this the author means other acids the point is of considerable importance and is made without adequate evidence.

Burr (7) found that *Amblystoma* larvae from which the nasal placoids had been removed snapped more frequently at moving sand-grains than did normals and failed to find motionless food which was found by eyeless animals with the nasal sac uninjured. Stunted growth of the forebrain resulted from removal of the nasal sacs.

Static and Auditory Receptors.—Buddenbrock (6) has made an extensive analysis of the structure and function of the statocysts of *Pecten*. The right statocyst is less differentiated than the left and its removal produces no disturbance in the mollusc's behavior. *Pecten* orients to gravity by rotation around any one of its three axes. Rotation around the hinge combines a reflex from the viscera and one from the left statocyst. Rotation around the long axis and around the long and vertical axes combined, as in free swimming, is conditioned wholly by the presence of the left statocyst. Kanda (19) describes the reactions of *Physa gyrina* to gravity but gives no evidence for the receptors involved in orientation.

Reisinger (33) extirpated the midbrain and cerebellum of the perch. With the destruction of the midbrain the balancing reflexes are completely lost. Loss of the cerebellum is followed by reduction of the force and coördination of single movements while attempts at balancing still recur.

Reed (32) traces the development of the fenestral plate of *Necturus* and discusses the phylogenetic bearing of its origin. Goodrich (15) makes a comparative study of the development of the middle ear with reference to the fate of the embryonic gill-elements.

Localization of sound by the albino rat has been studied by Barber (4). The rats were confined in an hexagonal pen, insulated from visual, olfactory, and tactile stimuli. Auditory stimuli could be directed from any point on the circumference of the pen and the rats were trained to go to the side of the pen nearest the source of sound. The average error of localization of clangs after training was 2 to 4 inches on the circumference of the box (20 to 40 degrees). No reactions were obtained to pure tones. Hunter (18) has continued his studies of the auditory sensitivity of the rat, confirming his earlier work. The animals could not be trained to react to tones from single forks or to combinations of such forks. They reacted to the Galton whistle but did not distinguish it from the accompanying noises and did not react to it when these were eliminated.

Sensitivity to Light.—The polemic articles of Loeb and Wasteneys (23, 24, 25) justify a plea for fairness in criticism, particularly as the authors employ the same logical method which they condemn in Hess. They determined the relative stimulating effects of different parts of the "carbon-arc spectrum" for various micro-organisms and conclude that there is no sharp distinction between the photosensitivity of plants and animals. The energy of their lights, selected "with the aid of prisms and mirrors" was absolutely uncontrolled so that their results are neither reproducible nor comparable with those of other workers. Hess at least distinguishes between wave-lengths, energy, and stimulating effect. These authors seem to have forgotten that wave-length and energy are not synonymous.

In a preliminary report Mast (26) describes apparatus for determining the relative effect of monochromatic lights for micro-organisms. Energy measurements were made but the results given for various protista are not corrected for these. As is to be expected from the different spectrometer systems there is no agreement between the results obtained by Mast and by Loeb and Wasteneys for the same organisms.

Arey (2, 3) gives an outline of the development of theories of retinal function. Movements of retinal pigment are established for amphibia and birds, less certainly for mammals. Changes in the form of the cone myoid under light have been observed in all vertebrates. The activities of the rod myoids vary with different classes. No uniformity of retinal movements exists throughout the vertebrate classes. Detwiler (13) finds in three species of tortoise and a lizard only cones in the retina. Light induces migration of pigment, contraction of the cones, and other changes.

Kranichfeld (**20**) observed that bees restrict their visits, in any one locality, to flowers reflecting long, or to those reflecting short wave-lengths and urges this fact in support of von Frisch's view of dichromatic vision in insects. Spurgeon (**36**) describes the eyes of three species of blind cave-dwelling crayfish.

Mast (**27**, **28**) contributes the most important study of vision in fishes that has yet appeared. Flounders assume a color closely similar to that of the background on which they lie and show characteristic differences for each wave-length as well as for different shades and patterns of gray. The stimulus to adaptation is received through the eyes and depends to some extent upon the relative illumination of the substratum and the light coming from above. The fusion rate on the retina is practically equal to that of man. Discrimination between dots of 2 and 3 mm. was found. Some evidence for the selection of substratum upon the basis of wave-length, intensity, and pattern is presented.

The experiments of Fletcher, Cowan, and Arlitt (**14**) upon chicks hatched from alcoholized eggs suggest a slight visual defect as the only result of injury to the eggs but this point is not considered by the authors.

Using the Helmholtz purified spectrum, Watson (**37**) determined the limits of the visible spectrum for the chick to lie at about $\lambda = 3{,}950$ and $\lambda = 7{,}150$; for the homing pigeon at about $\lambda = 4{,}200$ and $\lambda = 7{,}120$. The curve of threshold stimulating effect of the spectral lights for the fowl is similar to that of man, with its apex at $\lambda = 5{,}200$. The bearing of the spectral limits found upon theories of homing is discussed. Lashley (**22**) tested the relative stimulating effects of monochromatic lights for the light and dark adapted fowl, using the Yerkes-Watson apparatus, and obtained some evidence for the Purkinje phenomenon. Differential reactions to wave-lengths were established between $\lambda = 6{,}500$ and $\lambda = 5{,}200$ and between $\lambda = 5{,}880$ and $\lambda = 5{,}000$, and these persisted in spite of extensive changes in the relative energies of the lights. Yerkes (**39**) summarizes the study of color-vision in the ring dove which was reviewed here last year.

Patten (**31**) has made an instrument for directing a small beam of light which should prove useful in the study of the localization of photo-sensitive areas in invertebrates.

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HABIT-FORMATION AND HIGHER CAPACITIES IN ANIMALS

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The most important experimental work of the year includes studies of habit-formation as affected by strength of the incentive, age, distribution of effort, drugs, and sensory factors; studies of the limits of learning-ability of animals required to respond to a stimulus after a period of delay; and studies of situations in which the constant factor is relational.

Dodson (5) presented 18 cats with the problem of choosing the more strongly illuminated compartment of a Yerkes experiment-box. The order of presentation was irregular. The incentive to correct choice was the avoidance of punishment. The animals were divided into three groups according to the strength of the current through the primary coil of an inductorium, which served as the source of punishment. For a fairly difficult problem, a shock of medium intensity proved optimal; for a less difficult problem the kittens receiving the strongest shock required in the average 55 trials as against 60 trials for those receiving the medium shock; and for an easy problem, those receiving the strongest shock required 35 trials, those receiving the medium shock, 50 trials, and those receiving the weakest shock, 75 trials, for perfecting the habit.

Fletcher, Cowan and Arlitt (7) studied inherited and acquired reactions of normal chicks as compared with chicks hatched from eggs treated with distilled water and with alcohol, and with eggs which had been perforated and sealed. Alcohol *per se* has no specific effect other than that attributable to malnutrition during incubation, and produced as readily by other agents. Chicks hatched from eggs which had been tampered with differed from normal chicks in showing less caution in jumping from heights, and in slower acquisition of the maze-habit and discriminative associations. The reactions of pecking and drinking and the processes of inhibition are alike in normal and abnormal chicks. Imitation is not a factor in the growth of the pecking reaction; and the authors

differ from those students who have found chicks to be positively phototropic.

Hubbert (**8**) trained five groups of rats on a maze-problem. The ages of the groups at the beginning of training were 25, 65, 200, 300 and 500 days, representing the stages of youth, sexual maturity, maturity, senescence and senility. Records were taken in terms of time and distance, errors being disregarded. The effort required for perfection of the habit, as well as the time required for the execution of a perfect run, vary directly with age. Sex-differences are negligible, except that the males of middle age learn more quickly than the females. The time of execution of a perfect run after the habit has been perfected is less for females than for males. No advantage was gained by working at night rather than in the day-time. Continued practice after perfection of the habit did not result in shortening of the time. Rapidity of learning may be predicted from the family-group. The most rapid stage of improvement occurs earlier in the learning-process of the younger animals than of the older ones.

Myers (**15**) fed a pig several times daily in one of two compartments, *A* and *B*, requiring the animal to learn the pathway to *A* first. The errors comprised 33 per cent. of the total responses to *A* and 5 per cent. of the total responses to *B*. The results exhibit the persistency of the first of a series of habits, and the fact is presented as significant.

Ulrich (**21**) trained white rats in the Watson circular maze and in the opening of two puzzle-boxes. The animals opened one box by lifting a latch with the nose, and the other by depressing an inclined plane at the side of the box. A minimal time and the elimination of observable useless movements constituted the criterion of a perfected habit. The questions studied were whether the giving of a large or a small number of trials a day makes for more efficient learning of a single problem; whether the optimal method of learning a single problem also holds in the learning of two or more problems concurrently; and whether two or more problems are learned more economically when attacked successively or concurrently. When two problems were learned successively, the rats given one trial a day required the smallest number of trials for the perfection of the habit; and the group given three trials a day required fewer trials than the group given five trials a day. A small group given one trial every third day promised better results than any of the regular groups. When three problems were at-

tacked concurrently, the proficiency of the rats given one, three and five trials daily stood in the order named. A much larger total number of trials was required by the groups learning the three problems concurrently than by the groups learning them successively. For the learning of the problems in the fewest number of days, five or more daily trials were necessary. Differences in retentiveness were unimportant.

Vincent (22) continued her work on sensory control of the behavior of the white rat in the maze, and found that in relative effectiveness of the different sensory clues on accuracy, the olfactory maze leads; the maze without walls stands next; and the black-white and the ordinary mazes are of about equal value. A comparison of the total errors made in the first three alleys with those made in the last three show that the final members of the series were mastered first. The comparison holds for individuals as well as for groups.

Walton (24) tested the influence of distracting stimuli on the delayed reaction of the dog to light. The home-box was sometimes rotated so that the animal did not face the food-compartments during the period of delay; and the dog's attention was also directed to a bit of meat or to the activities of the experimenter during the delay-period. The author found that discrimination of four compartments was retained during a one-minute period of delay, and discrimination of fewer compartments for a longer time; that visual, olfactory and auditory distractions could be overcome; and that visual and olfactory secondary cues could be eliminated without causing permanent disturbance of training.

Cole (4) contends that Hunter's work on the delayed reaction in raccoons, if consistently interpreted, would tend to confirm the results which Cole drew from his own work: namely, that the animals possessed a mechanism which functioned as visual representation; and that there is no evidence which justifies the assertion that such representation is "imageless" in type. Cole also emphasizes that the procedure of Gregg and McPheeters, who attempted "to demonstrate the inadequacy of Cole's experiment," was not analogous to Cole's procedure; since they deliberately attempted to train the animals to respond to constant factors which Cole had tried to keep variable and ineffective. Cole's paper is somewhat polemic, having been influenced by the phraseology in which the Chicago authors presented a part of their critical discussion of Cole's work. Hunter (9) replies that the ideational function ascribed to the raccoons and to one child was strictly sensory in content and could not

be visual; that the content need not copy the original stimulus in order to represent it; and that in this case it was probably kinæsthetic. If Hunter could accept as a substitute the physiological correlate of kinæsthesia—*i. e.*, a muscular response not grossly observable—his interpretation and Cole's might readily be reconciled. Such muscular activity is held by some to be an essential condition of visual imagery, and indeed the only functional factor. Whether the raccoons should be accredited with imaginal content in the circumstances would then seem to depend on the metaphysical presuppositions adopted.

The Elberfeld horses received their share of attention during the year. Schröder (18) and Schneider (17) continue a discussion started in 1913 as to whether the horses' alleged mathematical ability is innate or acquired. Müller (15) communicates a private letter from F. Faustinus, who in 1913 investigated these claims, with special interest in the possibility of sleight-of-hand trickery. He discovered that it was actually being used by the stable-keeper—an individual of no mean ability. The latter had mastered a system of rapid evolution of the second, third and fifth powers of integral numbers, and kept at hand a table of the evolution of fourth powers. When the horse was presented with a mathematical problem, it would begin tapping, and continue until the keeper signalled it to stop. Faustinus found that *Muhamed* reacted to slight head-movements given by the keeper and visually perceived. The keeper could hold the horse's attention from a considerable distance outside the stable. When this communication was prevented the horse tapped at random. Faustinus learned the system of signals and thereafter could work alone and obtain any answers which he desired. *Hänschen* and *Berto*, the two other horses, were also dependent on the keeper's proximity and knowledge of the answers, but Faustinus was unable to ascertain the nature of the signals, further than that they were not visually perceived. He found the keeper extremely tricky, however; and never got correct answers from the horses except when the keeper was within hearing. Krall requested Faustinus to cease his investigation when the latter informed him of the general trend of the results, Krall maintaining that they no longer served any purpose in which he was interested. Faustinus insists, however, that Krall's honesty is unimpeachable, and that the latter is simply the victim of a hoax perpetrated by the keeper. He also emphasizes the extremely bewildering character of the setting, and declares that he would certainly have accepted

Krall's explanation of the behavior of *Hänschen* and *Berto* had he not previously discovered the fraud in the case of *Muhamed*, and thus been led to watch the keeper more closely.

Moekel's (14) article is not accessible to the reviewers, who depended on Meumann (13) for a summary of its contents. *Rolf*—an Ayredale belonging to Frau Moekel—is described as having exhibited an ability exceeding that claimed for Krall's horses. His superiority consisted in the greater spontaneity of his activities. It is said that he developed, without training, a system of communication by tapping; that he showed an early fascination for excercises in mental arithmetic; learned to decipher his mistress' typewriting; assisted her in devising an alphabetical form in which the position of each letter could be indicated by tapping; insisted on spelling phonetically; learned to distinguish Sunday from other days in the calendar by its being printed in red; signalled inquiries when in doubt; and exhibited an adherence to definite ethical principles. Meumann was disposed to accept the report in good faith, and to treat it as epoch-making. The present reviewers confess to a strong skepticism. The experiences of Moll and Pfungst with *kluge Hans* and of Faustinus with Krall's horses indicate that even eminent scientists may be hoodwinked into too hasty a dismissal of the possibility of "unconscious" assistance or of fraud. The present case has many earmarks of those which have been exposed.

Yerkes (25) criticises the present methods of recording observations, and urges that automatic recording devices be developed so as to nullify the "observational imperfections of the experimenter."

Yerkes (27) also describes his recent work on the behavior of monkeys and an ape in the multiple-choice situation. The animals were severally fed in nine food-boxes in irregular order. At each trial a group of contiguous boxes, varying in number from two to nine, were open. The box to be chosen was indicated by its position in the presented group, regardless of the place of the group in the series of nine. The boxes to be selected were in problems (1) the first on the left; (2), the second from the right end; (3) alternately the first at the left and the first at the right; and (4) the one in the middle, of the presented group. The animal was fed in the box to be selected, and punished for entering a different box by being confined for a definite time in the latter. The same order of presentation was given in each series of ten trials. After each problem had been learned, a different order was given, the problem remaining the same. This control-test showed whether the animal had simply

memorized the original order of presentation, or had chosen the correct box according to its position in the presented group. In the latter case it was assumed that the effective factor had been relational, and that the animal's behavior was analogous to ideational behavior in man. The degree to which the animal adhered to a typical trial-and-error method of eliminating wrong responses, or resorted to more complex methods, was taken as an index of the relative importance of "ideational" methods in the learning-process.

Three out of eleven animals were satisfactory subjects: one *M. rhesus*, a *M. cynomolgos*, and an orang-utang—all males. When the work had to be dropped, the first animal had solved the first three problems and was well along with problem 4; the second had solved the first two; and the last animal only the first one. The monkeys were more disposed to a trial-and-error mode of selection than the orang, and therefore made much more rapid advancement in learning. The author therefore concludes that the number of trials required for mastery of a problem is not a safe criterion of "intelligence." He regards the learning record of the *cynomolgos* as indicating a lower order of intelligence than that of the *rhesus*, and points out a striking dissimilarity between the types of curves yielded by the monkeys and by the ape. He regards the orang as having indicated an "insight" into the problem, in that the latter was suddenly and finally solved at the end of 290 trials during which a maximal percentage of errors had occurred without any indication of improvement.

Yerkes believes that his monkeys yielded relatively abundant evidences of ideation, but scanty evidence of what Thorndike calls "free ideas" or what Hobhouse calls "articulate ideas." As evidence of ideation in the ape he urges (1) the use of several different methods; (2) the sudden transition from method to method; and (3) the final and perfect solution of problem 1 without previous diminution of initial errors, etc. The critic who is disposed to insist on a different interpretation of the experimental data need not quarrel with the author. He presents in detail the data from which the conclusions are derived, so that the facts are readily separable from their interpretation.

Burtt (2) presented the first multiple choice problem of Yerkes to three adult white rats, one of which was inbred. They solved it in 200 trials or less; and a younger inbred rat solved it in 350 trials. He presented two rats with the second problem, but neither solved it in the 800 to 900 trials given them.

The observations reported by Shepherd (19), Eaton (6) and Maud (12) were casual. Their accounts abound in "anthropopsychisms."

Smith (20) summarizes the results obtained by a number of earlier experimenters in learning capacities, and treats them under the point of view that mental phenomena are observable and traceable in evolutionary process. Thomson (21) gives a naturalistic presentation of some of the same facts in illustration of the theme indicated by the title of his book. The work should have great stimulating value for beginners, although many impressions which it designs to make will hardly survive critical treatment.

Bose (1) used a "resonant recorder," the needle of which vibrates instead of making continuous contact with the recording surface, to obtain graphic records of the movements of certain plants in response to electrical stimuli. He noted a group of responses which strikingly resemble those made by animal tissue under similar conditions. This group includes a latent period, a daily rhythm of response, with decrease of irritability during the early morning hours, a decrease of magnitude of response after administration of chloroform, arrest of pulsations under ether, suffocation by CO_2, response to summation of stimuli, and unsteadying effects of alcohol. Kaempfert (9) discusses the work of Bose at length, and regards it as proving that plants have a nervous system. He also notes that plants have a death spasm, which always occurs at the same temperature.

Lillie (10) argues that behavior to be regarded as purposive need not be distinctive of living organisms alone. He defines adaptation as a species-conserving characteristic, which includes protective resemblance, radial and bilateral symmetry, antero-posterior and dorso-ventral differentiation, food-taking reactions, hibernation and reproductive activity.

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SPECIAL REVIEWS

The Mechanism of Mendelian Heredity. T. H. MORGAN, A. H. STURTEVANT, H. J. MULLER, C. B. BRIDGES. New York: Holt, 1915. Pp. xiii+262.

The book under review has been accorded wide recognition by students of Genetics in this country. The central theme running throughout the text is the correlation of the phenomena of Mendelian heredity with the chromosomal mechanism of germ cells. To the support of their contentions, the authors have succeeded admirably in marshalling the facts which have been brought to light in their extensive studies on the little fruit fly *Drosophila.* Almost every important point in Mendelian heredity has been illuminated both cytologically and genetically by results obtained in the laboratories of the University with which the authors are connected. The book therefore largely represents the results and conclusions of this school of biologists. One of the many excellent features to be found in the general make up of the book is the matter of illustration. Most of the figures and diagrams are new, with the result that the text is free from shopworn illustrations.

Every one of the nine chapters is worthy of careful reading and study, but those deserving especial mention are Chapters III, IV, VI, VII, and VIII, dealing respectively with Linkage, Sex Inheritance, Correspondence between the Distribution of Chromosomes and of Genetic Factors, Multiple Allelomorphs, and Multiple Factors.

The central idea of Mendelian heredity is segregation, and according to the factorial hypothesis the term "factor" is "used for something which segregates in the germ cells, and which is somehow connected with particular effects on the organism that contains it." The factors are supposed to have their "loci" in the chromosomes. Since in any given form the number of specific characters is in excess of the number of chromosomes, it follows that each chromosome must carry more than a single factor. Experiments have shown that in several different species, and in *Drosophila* especially, groups of two or more characters often tend to stay together in successive generations of a cross. This tendency of

factors to stay together is called *linkage*. The linkage theory finds its strongest support in the fact that linked characters follow the same law of distribution as the chromosomes in gametogenesis and fertilization. This is especially clear in the case of sex-linked characters, which follow exactly the same distribution as the sex-chromosomes.

The study of linkage has brought to light another phenomenon known as *crossing over*. "If two factors lie in the same member of a chromosome pair we should expect them always to be found together in successive generations of a cross unless an interchange can take place between such a chromosome and the homologous chromosome derived from the other parent." Evidence has been found which indicates that pieces of homologous chromosomes do sometimes interchange segments, and this process of interchange is called crossing over. An opportunity for such an interchange to occur is offered during the course of germ-cell formation, at a critical stage in which homologous chromosomes are temporarily united in pairs. During this period the members of a pair often twist about each other, and later in coming apart an interchange of pieces might readily occur. One of the interesting points about crossing over is the fact that it never occurs in the male. In the female the amount of crossing over is ordinarily constant for any given combination, but is different for different combinations.

Another interesting point about crossing over is that it offers an opportunity to determine the loci of factors in the chromosome. "The chance that such a process of crossing over will occur between any two given points on the chromosome should obviously be greater, the greater the distance between those points. If then the Mendelian factors lie along the chromosomes, the amount of crossing over between any two of them will depend on their distance apart. Should two points lie near together a crossover will only rarely occur between them; if they lie further apart the chance of such a crossover taking place at some point between them will be greater. From this point of view the percentage of crossing over is an expression of the 'distance' of the factors from each other." By determining the percentage of crossing over in various combinations, the authors have been able to plot the loci of the various factors in each of the four chromosomes which characterize the cells of *Drosophila*. They are thus able to show the linear arrangement of factors in the chromosomes, which is one of the newest developments in Mendelism.

Finally, we may mention another line of evidence which strongly supports the chromosome interpretation of heredity. We refer to non-dijunction, in which the abnormal behavior of the sex chromosomes in the maturation of the egg can be correlated with an identical abnormal distribution of all sex linked factors.

The points here cited are only a few of the many to be found in this book, but they will serve to illustrate the more important phases of Mendelian heredity which are now receiving the attention of geneticists. The student of Comparative Psychology must necessarily be interested in these problems, for sooner or later he will have to deal with them.

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The Investigation of Mind in Animals. E. M. Smith. Cambridge: Cambridge University Press, 1915. Pp. ix+194.

This volume was written to present "a brief account of the modes of procedure employed by Animal Psychology, its aims, trend and the general nature of the results hitherto obtained."

The first chapter on protozoan behavior is concerned mostly with the reactions of paramecia. The tropistic and the trial and error interpretations are contrasted. Reversal of reaction by change in the physiological condition or by a mere variation in the intensity of the stimulus counts in favor of the trial and error theory, which alone admits of "plasticity."

Retentiveness, habit formation, associative memory and sensory discrimination are reviewed in the second and third chapters. Some of the familiar studies on learning the maze, and auditory and visual discrimination are outlined, and a reference is made to the work of Pawlow.

In chapter four the author emphasizes that in an instinct we have an impulse and the satisfaction of the impulse. The impulse constitutes the instinct, and, in the absence of a proper stimulus, it may seek satisfaction until a suitable object is encountered. An instinct is neither a simple reflex nor a mere chain of reflexes. The effects of practice and of structural maturity are considered.

The chapter on *Homing* treats mainly of the travels of ants, bees, and pigeons. After a review of several studies of *Imitation*, the conclusion is reached that "no case has, as yet, been recorded which cannot, in the last resort, be adequately analyzed on the 'stimulus and response' basis, the object or situation, either in itself or through

association, suggesting the appropriate reaction." The range of attention may be narrowed to the vital part of the apparatus. Neither learning from "putting through" nor imitative behavior can be a criterion of intelligence. With the possible exception of the method of delayed reactions, no test as yet applied demonstrates "that animal learning is anything more than a process of association, on the perceptuo-motor level. The one point that clearly emerges is the need for new methods of inquiry."

The book as a whole is a rather brief survey of the topics indicated with little that is original in its treatment. It should be added that this is just what it pretends to be. It would probably be of use in a short course, and the general reader will doubtless find it worth while.

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The Study of Human Behavior. R. M. Yerkes. *Science*, 1914, **39**, 625–633. *A Study of the Crow* Corvus Americanus *Aud. by the Multiple Choice Method.* C. A. Coburn & R. M. Yerkes. *J. of Animal Behav.*, 1915, **5**, 75–114. *A Study of the Behavior of the Pig* Sus Scrofa *by the Multiple Choice Method.* R. M. Yerkes & C. A. Coburn. *J. of Animal Behav.*, 1915, **5**, 185–225. *The Ideational Method of Studying the Behavior of Man and Other Animals.* R. M. Yerkes. *Psychol. Bull.*, 1915, **12**, 330–331. *Methods of Studying Ideational Behavior in Man and Other Animals.* R. M. Yerkes. *Psychol. Bull.*, 1916, **13**, 93–94. *The Mental Life of Monkeys and Apes: A Study of Ideational Behavior.* R. M. Yerkes. *Behav. Mon.*, 1916, **3**, no. 1, Pp. iv+145.

The above list includes all references to date on the Multiple Choice method of studying behavior. Inasmuch as this material lays down the essentials of purpose, method and interpretation as conceived by the authors, a comprehensive review and criticism cannot be amiss.

The Multiple Choice method presents the subject tested several series of simultaneous visual stimuli from which he is to select one stimulus. Success is rewarded and failure is punished. The experimenter so arranges the presentation of stimulus series from trial to trial that the stimulus to be selected bears (for the experimenter) a certain constant relationship to the whole. Thus, to be concrete, in the work here reviewed, 2 pigs, 2 crows and 3 primates

were tested with an apparatus which made possible the simultaneous presentation of nine stimulus boxes. The number actually presented to the animal at any one trial might vary from two to nine; but the boxes that were presented, *i. e.*, whose front doors were opened, were always contiguous boxes. Each box contained food, but any particular bit of food was only accessible to the animal after he had entered the proper box. This box might be: (1) the one at the left end of the row of open boxes, (2) the one at the right end, (3) alternately the one at the left end and the one at the right end, (4) the middle box, (5) the second one from the left, or (6) the second one from the right, etc., as the experimenter determined. Whichever relationship was decided upon remained constant until the animal reacted correctly 10 times in succession or until such success was despaired of by the observer. There is no reason to suppose that the animals derived cues from the experimenter, his method of operating the boxes or from the food. Control series were introduced in some cases to determine whether the subjects were responding to particular settings or whether they had developed the capacity of reacting to the proper box in any setting.

The 2 crows each learned to solve problems one and two as listed above within some 50 trials, but failed even to improve consistently within 500 trials on problem 5. The chief reaction tendency manifested was that of entering consecutively the boxes either to the right or to the left of the first choice until successs was attained. Controls for particular settings were not used.

The 2 pigs each learned to solve problems two, three and five but failed to achieve complete success in problem four as listed above. In this last problem the pigs could succeed with short visual extents (three open boxes and to some extent with five). Apparently no clear cut reaction tendencies appeared. Controls for particular settings were used only in problem three. The results although not clear cut indicate a fairly general mode of response.

Of the 3 primates used by Yerkes in the last study two were macacus monkeys and one an orang utan. One monkey was tested on problems one, three and six. The first and last were solved. The second monkey succeeded with the three problems just mentioned, but failed on number four. The orang utan mastered problem one, but failed on number two. Control tests indicated that the first monkey was responding to specific settings. This is true also of the second monkey on problem three; but this second monkey reacted correctly to any series for his other two problems and the ape did as well on the one problem that he mastered.

No detailed analysis is offered for the failures made by the various subjects, although there are several possibilities aside from defective ideas.

This series of papers presents a very interesting case of the development of an interpretative point of view. In the beginning Yerkes's attention was directed to a study of reaction tendencies in the light of Hamilton's previous work. In the final papers reaction tendencies are rapidly slipping into the background. The emphasis is now upon the Multiple Choice method as a means of studying ideational behavior,—quite a different matter. In the reviewer's opinion the multiple choice method is applicable only to the study of reaction tendencies. Yerkes has not defined these, but his papers make clear that they are position habits which appear in the course of an animal's attack upon two or more simultaneously presented stimuli. The new element involved in his work and Hamilton's lies in the intensive study of the position (kinesthetic) habits which all experimenters have noted but which no one has sufficiently analyzed. The ideal of this work is undoubtedly to bring out phyletic differences in reaction tendencies.

The Multiple Choice method is important for the study of representative factors, ideational behavior, only if one of two (or both) assumptions are made; (1) The animals tested possess these factors and this method gives an opportunity for their expression. Or, (2) the problem must be solved by a perception of relationship and is therefore an ideational problem. Many quotations could be given indicating that Yerkes is apparently making both of these assumptions. It must be remembered with respect to the first one that if an animal possesses representative factors, it may almost never use them and then only when forced to in the absence of the stimulus at the moment of response. The second assumption has not been proved to present the only method of solution. Indeed Yerkes points out that most of the reactions were to particular settings. Where the reaction finally could be made to any setting, there is certainly a general response; but it has just as certainly not been shown that the stimulus for this response is a perception of relations. It is very important to remember that the subject is being taught to localize a certain point (box) in a variable visual extent (number of boxes). Because he can so localize, it does not follow that he perceives space relations. I feel sure that a dog could be taught to pick up sticks of variable length by either end or by the middle. Yet one would not therefore argue that he perceived the space relationship.

It is very difficult to study complex behavior without falling more or less into anthropomorphisms, and this is particularly true with primate subjects. Even Yerkes has heard the siren call. I quote one excellent example, and there are others: One monkey had hurt his foot in one of the boxes. Later during a test, a scraping sound occurred under the box while the monkey was in it. ". . . the instant the entrance door was opened, he jumped out excitedly. *He made no outcry, but as soon as he was out of the box, sat down, and taking up his right foot, examined it for a few seconds.* Having apparently assured himself that nothing serious had happened, he went on unconcernedly about his task. . . . Psychologically dedescribed, the sound induced an imaginal complex equivalent to the earlier painful experience. The beheavior seems to the writer a most important bit of evidence of imagery in the monkey" (p. 38).

From Yerkes's statements about the Multiple Choice method his conclusion is unexpected, especially when one sees that he finds probably his chief evidence for ideational behavior not in the solution of multiple choice problems as such, but in the following partly accessory data: (1) The learning curve for the ape descends from high to low over night. (2) A comparative study of a child and the ape upon a box stacking experiment revealed a close similarity, although the child manifested a greater variety of modes of procedure. "No unprejudiced psychologist would be likely to interpret the activities of the orang utan in the box stacking experiment as other than imaginal or ideational" (p. 97). The reviewer fears there are many psychologists who, on the basis of data so far available, would interpret the behavior in stimulus-response terms. The test is of particular human interest because of the suggestion it contains for future comparisons among the primates. The first point, concerning the form of the learning curve, has been debated before in the literature although never upon the basis of such a clear cut rapid drop as the ape's curve presents. In evaluating the present case, it should not be forgotten that the ape in attacking difficult problems was continually shifting suddenly from one method to another. One of these shifts was to the proper method. Hence the curve. The mere fact of "varying means" is found in all animals and the speed of the shifting seems correlated with the urgency of the need.

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Human Physiology. L. Luciani. (Trans. by F. A. Welby. Ed. by G. M. Holmes.) Vol. III, Muscular and Nervous Systems. London: Macmillan, 1915. Pp. x + 667.

Although the general work of Luciani is called human physiology, the present volume deals mostly with the physiology of vertebrates lower than the human. In ten chapters which cover over 600 pages are given the main facts respecting the muscular and nervous systems. One chapter deals with the general physiology of muscle, one with the locomotor apparatus, one with phonation and articulation, and the remaining seven with the nervous system.

This volume will be found valuable to psychologists who have interest in behavior, but especially to those who, irrespective of their objective or subjective standpoints, feel the necessity of knowledge of the functions of the different sections of the nervous system. Not only are the main facts recorded and dealt with in very readable fashion, but the work has a special value in that a large body of not widely known Italian literature on the functions of the nervous system has been included. Unlike many physiological texts the book deals frankly with psychological matters, and one of the final paragraphs is well worth quotation.

"By its investigations into the material conditions of human activity, physiology allies itself with the moral sciences. In the twentieth century it will pursue the scientific analysis of psychophysical phenomena without preconception or prejudice. It will not be hampered as in the past by animus to the concept of the soul, nor, on the other hand, will it fail to recognize that psychical development, even on the ethical side, depends to a large extent upon the somatic substrate."

Although the view is expressed that in animals there are combined cortical areas for both sensory and motor functions, in man it is admitted that the precentral area is almost strictly motor and the postcentral almost strictly sensory. The cortex, however, is not the only part of the brain which may subserve sensory functions. With respect to vision, for example, it is said that in a dog all or almost all of the so-called visual cortex may be removed without producing a blindness, but the facts upon which this conclusion is based we may interpret in a different fashion. In man, however, the blindness from a lesion in the calcarine area is more apt to be complete and permanent. Luciani appears, therefore, to hold to the view that in the lower animals there is a combination (or lack of differentiation) of the sensory and motor components

of the cortex, and that there is an increasing areal differentiation of the cellular combinations as the brain develops phylogenetically. If this were more widely accepted we should have less useless controversy over the differences of interpretation by those who experiment with animals and those who observe patients with cerebral lesions.

The chapter on the cerebellum is one of the most valuable in the book. It contains an account of extensive work by the author and his pupils, which have helped to simplify our notions regarding the functions of that organ. The suggestions of the mental functions of the cerebellum are of considerable interest.

Some of the psychological statements are not as exact as could be desired, but the meanings are evident. The assumptions of certain mental-cerebral relations are those usually found in the writings of clinical neurologists. When a patient becomes aphasic 'he has lost certain memories or ideas' although 'his intelligence remains intact,' and in that condition there may be affected areas or centers for the 'motor images of words,' for 'phonetic verbal images,' and for 'visual verbal images.' These interpretations of clinical phenomena are also equalled by those referring to the activities of animals after the removal of parts of the brain. In Rothmann's dog with the cerebrum removed we are told that "mental activity was not entirely absent," and this is shown by the fact that the animal "learned to adapt its movements to the oblong form of its cage." So also, the pigeon with the cerebrum removed "shows marked defects which are most readily explained as the loss of memory impressions of previous sensations, owing to loss of intelligence properly so-called." Perhaps, however, we should not censure too severely a mere physiologist for anthropomorphisms which are paralleled in a percentage of contributions by comparative psychologists.

The author quotes with approval the opinion expressed by Foster that activities of all parts of the nervous system, independently or collectively, are accompanied by "some amount of consciousness." The spinal animal, therefore, would have a form or degree of consciousness or some primitive psychical processes.

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